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Comparison of the effectiveness of electrolysis and microelectrolysis in the treatment of musculoskeletal pain: a systematic review

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Abstract

Introduction. Musculoskeletal pain (MSP) is a frequent reason for consultation; its high prevalence is a concern. Recently, different electrolysis modalities have appeared to reduce MSP, although studies supporting their use and comparing them are limited. This study compared the effectiveness of electrolysis modalities in MSP treatment.

Methods. The PubMed, Scopus, Web of Science, CINAHL, and ScienceDirect electronic databases were searched for randomized clinical trials (RCTs) (last update: September 4, 2020). Three independent researchers reviewed titles and abstracts to determine article eligibility. Risk of bias and quality were assessed with the Cochrane risk of bias tool and the PEDro scale. Pain reduction was the main outcome and changes in range of motion or disability/functionality constituted secondary results.

Results. Overall, 15 RCTs were obtained after eliminating duplicates and applying the selection criteria. Musculoskeletal conditions treated with electrolysis or microelectrolysis included myofascial pain (n = 3), patellar tendinopathy (n = 2), plantar fasciitis (n = 2), pubalgia (n = 1), subacromial impingement (n = 3), epicondylitis (n = 1), calcaneal tendinopathy (n = 2), and whiplash syndrome (n = 1). The studies had a low risk of bias and an average PEDro score of 9. They revealed pain reduction for electrolysis and microelectrolysis at the end of treatment and follow-up evaluations ($p < 0.005$), and functionality improvement for all experimental groups ($p < 0.005$).

Conclusions. Electrolysis and microelectrolysis treatments reduce pain and improve functionality in MSP conditions. Although both techniques are effective, comparative studies are suggested to determine therapeutic differences and user preferences.

Key words: electrolysis, electroacupuncture, electric stimulation, musculoskeletal pain, musculoskeletal diseases, systematic review

Introduction

Musculoskeletal pain (MSP) is a frequent reason for consultation, being the primary symptom of a variety of musculoskeletal system disorders [1]. Musculoskeletal disorders (MSDs) include injuries such as fractures, sprains, tendinopathies, tears, or joint diseases, generated by traumatic events, repeated activities, or degenerative processes [1, 2]. MSP affects people of all ages and its prevalence increases since adolescence to advanced age [1]. Furthermore, it has been recognized as one of the major causes of worldwide disability and social burden, observed in about a quarter of the population, with a rise of 20% in the latest decades [1–3]. MSP generates important physical consequences, such as mobility limitation, loss of dexterity, and functional capacity alteration; it is also estimated that about 8% of people with MSP require care related to disability [1–4].

When MSDs are persistent (more than 3 months) and without an early diagnosis, they can produce chronic MSP, with secondary consequences such as pain maintenance, movement fear (kinesiophobia), catastrophism, anxiety, and central sensitization, that is, a synaptic plasticity phenomenon that increases the central neural response to peripheral stimuli, which worsens the disability [4, 5].

MSP has become a public health problem owing to its social and health costs associated with recovery, medications, imaging, rehabilitation, or surgeries; it is also the main cause of labour productivity loss [6–8]. This creates a need to improve the quality of physical therapy treatments, as well as the care provided in MSP, to reduce the costs related with pharmacology and surgery [8–11].

Physical therapy utilizes a variety of electrical currents for pain management, generally emphasizing transcutaneous electrical nerve stimulation and medium frequency burst-modulated alternating current [12–15]. Recently, however, percutaneous procedures that use direct current (DC) have appeared to reduce pain and promote tissue repair in MSDs [16–23]. DC is characterized by a unidirectional charge flow, low voltage, and constant intensity, with biological effects that are not achieved with other currents [16, 17]. An example of these effects is musculoskeletal tissue electrolysis, chemical decomposition of molecules in solution resulting from DC flow; it generates electrophoresis (ion repulsion) and acidic and basic substance formation under the anode and the cathode, respectively. This organic reaction produces localized and controlled inflammation, circumscribed to the treatment area, promoting collagen synthesis and circulation increase, leading to a tissue repair process along with pain reduction [16–22].

Three examples of therapeutic electrolysis include percutaneous intratissue electrolysis (EPI®), percutaneous therapeutic electrolysis (EPTE®), and percutaneous microelec-

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trolysis (MEP®). These treatments are based on the application of DC by using acupuncture needles (percutaneous procedures) reaching high current densities (mA/cm^2) in tissues owing to the smaller surface of the needle [18–23]. In these procedures, the cathode is represented by the acupuncture needle, which is usually 0.3 mm thick and 25–32 mm long, while the anode, with a bigger surface area, acts as a dispersive electrode, closing the circuit in the skin [18–23].

Cathodic electrolysis is the result of sodium (Na^+) or potassium (K^+) ions interaction, with water molecule (H_2O) breakdown, a chemical response that produces synthesis of caustic substances, such as sodium or potassium hydroxide (NaOH or KOH), with a pro-inflammatory response. This is accompanied by a release of molecular hydrogen (H_2), an inhibitor of free radicals that concentrate in damaged musculoskeletal tissues; it supports the analgesic effects associated with the procedure [16–24]. Furthermore, the mechanical stimulation of the needle itself promotes tissue micro-rupture, enhancing the pro-inflammatory effects of galvanism [16, 19–24].

The main difference between EPI, EPTE, and MEP is the intensity of the current used, which is of the order of milliamps (mA) for EPI and microamps (μA) for EPTE and MEP [16–24]. Differences also appear in relation to the application time, which is shorter in EPI (interval applications of a few seconds) and longer in EPTE and MEP (interval applications lasting seconds or minutes).

If the reciprocity law (Bunsen-Roscoe law) is considered [25], the 3 techniques induce tissue electrolysis, only at different rate response because the current densities vary in magnitude in EPI, EPTE, and MEP, with ranges between 2.5 and 13.15 mA/cm^2, which depends on the chosen needle size [15, 16, 19]. Although the therapeutic effects could be similar, differences in the current density could translate into more comfortable or uncomfortable patient's clinical responses [22–24, 26]. Moreover, the 3 procedures can be supported with ultrasound-guided application to determine more specific sites of treatment, although applications without ultrasound support have been described for MEP in extremity MSDs on the basis of symptoms, palpatory anatomy, and clinical evaluation [16–24].

Thus, EPI, EPTE, and MEP are currently used in acute and chronic MSDs, including tendinopathies or muscle injuries, to reduce pain and promote tissue repair [18–24]. In addition, the incursion of MEP in the dermatofunctional area stands out, with its administration for the management of wrinkles, stretch marks, fibrosis, and neuropathic scars, which respond well to induced inflammation [22–24].

EPI, EPTE, and MEP seem to be good treatments to reduce pain in MSDs; however, as they are recent techniques, studies that support the effects of electrolysis are limited. Also, comparisons between the therapeutic results of the 3 techniques are scarce. Therefore, the objective of this systematic review (SR) was to evaluate and compare the scientific evidence published during the latest decade regarding the effectiveness of electrolysis modalities in reducing MSP.

Subjects and methods

This SR adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [27]. The research was registered electronically in the International Prospective Register of Systematic Reviews (PROSPERO) of the National Institute for Health Research (https://www.crd.york.ac.uk/prospero) under the identification code CRD42020208932.

Search strategy

The SR search was carried out in the electronic databases of PubMed, Scopus, Web of Science, CINAHL, ScienceDirect, and Physiotherapy Evidence Database (PEDro) with the last update on September 4, 2020. On the basis of the PICO (Population, Intervention, Comparison, and Outcome) framework, a search algorithm was developed to assess the effects of electrolysis and microelectrolysis in reducing pain (acute or chronic) in patients with MSDs [28]. The search included the keywords "electrolysis", "electroacupuncture", "electric stimulation", "intratissue percutaneous electrolysis", "microelectrolysis", "musculoskeletal pain", "tendinopathy", "myofascial pain syndromes", "myalgia", "acute pain", "chronic pain", and "analgesia" with the Boolean operators "OR"and "AND". The following algorithm was obtained: ((((((("Electrolysis" [MeSH terms]) OR ("Electroacupuncture"[MeSH terms])) OR ("Electric stimulation" [MeSH terms])) OR OR ("Intratissue percutaneous electrolysis")) OR ("Microelectrolysis")) AND (((((("Musculoskeletal pain" [MeSH terms]) OR ("Tendinopathy" [MeSH terms])) OR ("Myofascial pain syndromes"[MeSH terms])) OR ("Myalgia" [MeSH terms])) OR ("Acute pain"[MeSH terms])) OR ("Chronic pain" [MeSH terms])) OR ("Analgesia" [MeSH terms])).

After the search, each database yielded a certain number of articles, which were downloaded in the NBIB, RIS, or CIW formats. The files were analysed with the Rayyan tool, developed for the preliminary selection of abstracts and titles of articles (https://rayyan.qcri.org) [29]. Three independent researchers (M.D., I.R., and V.R.) analysed the titles and abstracts of the articles with the consideration of the selection criteria, classifying them in the categories 'included,' 'possible,' and 'excluded'. In addition, paper titles and abstracts were examined for the country of origin, author, affiliated institutions, and enrolment periods to identify and exclude duplicate publications. Articles in the 'possible' category were reviewed collectively with the aim to determine if they would be included in the final count. Each researcher recorded the reasons for article exclusion. Articles with incomplete abstracts were discarded from the analysis. The main variable of interest was the reduction of pain in MSDs treated with electrolysis or microelectrolysis, while changes in range of motion, muscle strength, and/or quality of life were included as secondary variables with respect to disability in the reported MSDs. In the selected papers, the study objective in accordance with the PEDro scale score was analysed, as well as the participants' demographic data, conflict of interest declaration, follow-up periods, assessment times, treatment protocols, electrolysis or microelectrolysis dose, and main and secondary outcomes [30, 31].

Selection criteria

The inclusion criteria were as follows: (1) randomized clinical trials (RCTs) or controlled clinical trials; (2) human studies; (3) participants older than 18 years; (4) articles published in the previous 10 years; (5) articles in the English language; (6) studies that used electrolysis or microelectrolysis alone or in combination with another intervention as pain management in MSD; and (7) comparison with other treatments, sham application, or placebo. In turn, the exclusion criteria involved: (1) case reports, SRs, meta-analyses, and literature reviews; (2) studies in animals or *in vitro*; (3) treatments with electrolysis or microelectrolysis in non-musculoskeletal conditions; (4) pain resulting from neurological disorders (e.g., hemiplegia, spinal cord injury, diabetic neuralgia); and (5) studies whose abstracts or texts were incomplete.

Article quality and risk of bias

The quality of the selected articles was evaluated with the PEDro scale (kappa coefficients of 50 and 79 for consensus generated by 2 or 3 evaluators) [30, 31]. Each researcher performed the assessment independently and any disagreement was subsequently discussed collectively until consensus was reached. RCTs with PEDro scale scores smaller than or equal to 5 were classified as low quality, while articles with scores higher than or equal to 6 were considered high quality (Table 1, see end of paper).

The risk of bias of the included articles was assessed with the Cochrane Collaboration risk of bias tool, considering the following criteria [32, 33]: (1) random selection of participants (selection bias); (2) allocation concealment (selection bias); (3) participant and staff blinding (performance bias); (4) blinding of result measurements (detection bias); (5) results with incomplete data (attrition bias); (6) selective reporting (reporting bias); and (7) other sources of bias. The risk of bias was classified as high, low, or unclear. Trials of poor methodological quality were those with 3 or more high risks of bias [33].

Ethical approval

The conducted research is not related to either human or animal use.

Results

The initial search strategy yielded a total of 6155 articles from the selected databases (PubMed, *n* = 3812; Scopus, *n* = 8; Web of Science, *n* = 1085; CINAHL, *n* = 1162; ScienceDirect, *n* = 88). With the Rayyan detection tool, duplicates were eliminated, which allowed to obtain a total of 4997 articles [29]. The main reasons for exclusion were: treatments with non-galvanic currents (transcutaneous or percutaneous), SRs/meta-analyses, literature reviews, case studies, another main result, absence of a comparison group, studies in animals or *in vitro*, and non-musculoskeletal disorders. After title and abstract reviewing, 24 articles were obtained between 'possible' and 'included'. Selection criteria were applied and agreement was reached for the 'possible' and 'included' articles; 9 were discarded and finally 15 RCTs were obtained for analysis.

The causes of paper exclusion were interventions with other electrical modalities (*n* = 4), other main outcome (*n* = 1), other type of study (*n* = 3), and non-musculoskeletal conditions (*n* = 1). Figure 1 shows the PRISMA flow chart and the selection process summary, while Figure 2 (see end of paper) depicts the risk of bias where no more than 3 risks of high bias were observed for the selected articles. Despite what has been described, 2 RCTs (13.33%) presented 3 high risks of bias and 2 involved unknown biases; these were also included in the SR to obtain a greater number of studies for

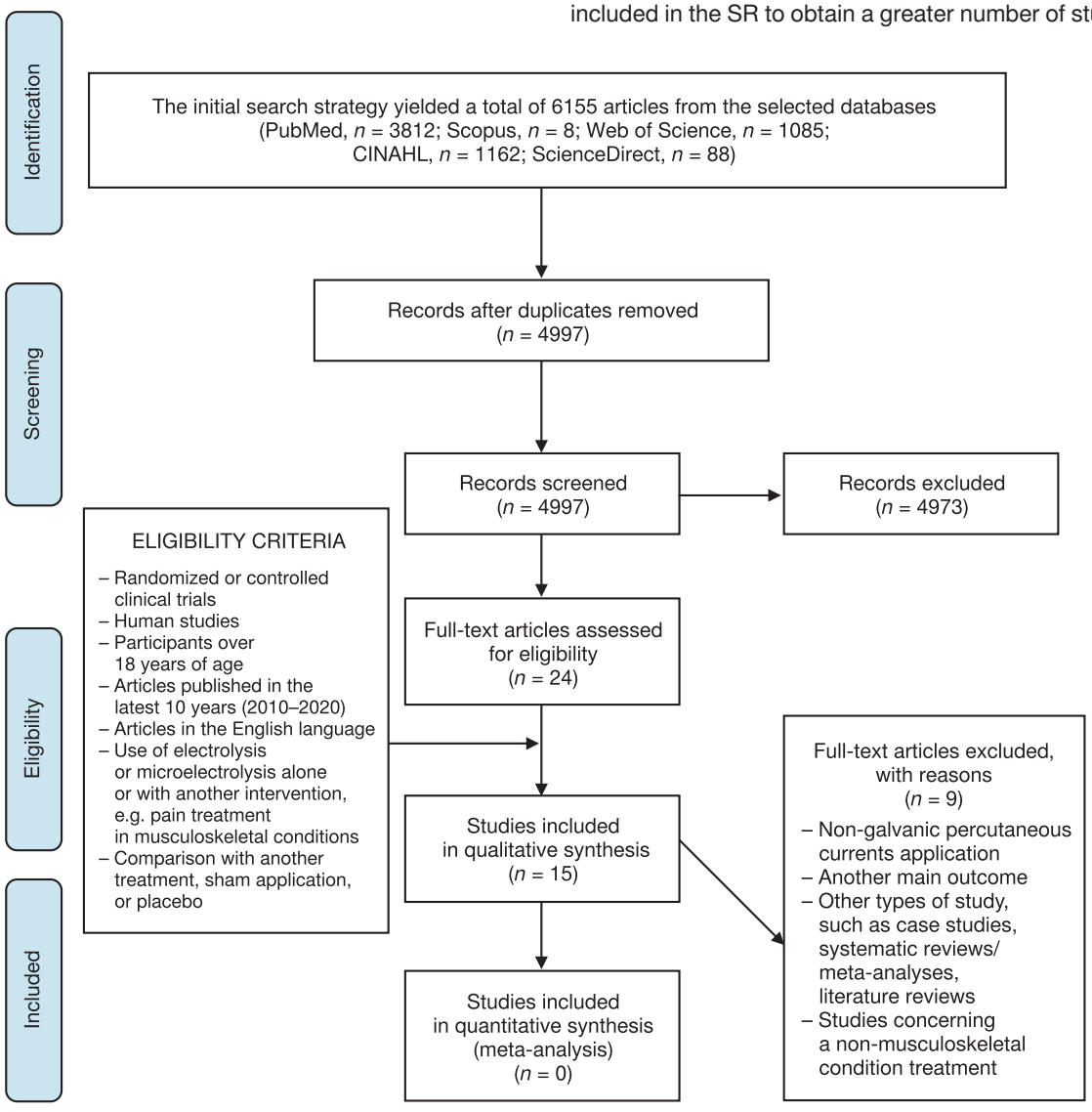

Figure 1. Flowchart of the studies included in the review in accordance with the PRISMA 2009 guidelines

analysis [21, 22, 32, 33]. A total of 10 articles (66.66%) exhibited a PEDro score higher than 5, with an average score of 9, for which they were attributed good internal validity [18, 19, 23, 24, 34–39], while 5 (33.33%) were rated with a score of 4 [21, 22, 40–42].

The reported MSDs treated were myofascial pain (n = 3) [18, 22, 23], patellar tendinopathy pain (n = 2) [21, 39], subacromial impingement (n = 3) [34, 35, 37], talar pain (n = 1) [19], plantar fasciitis (n = 1) [40], pubalgia (n = 1) [36], lateral epicondylalgia (n = 1) [38], calcaneal tendinopathy pain (n = 2) [24, 41], and acute whiplash syndrome pain (n = 1) [43]. Table 2 (see end of paper) summarizes the selected RCT characteristics, as well as the primary and secondary outcomes of interest.

Table 3 (see end of paper) shows that 6 articles (40.00%) reported EPI application to reduce pain in temporomandibular myofascial conditions (n = 1), patellar tendinopathy (n = 2), plantar fasciitis (n = 1), pubalgia (n = 1), and acute whiplash syndrome (n = 1) [18, 21, 36, 37, 39, 42], while 4 RCTs (26,66%) used MEP in myofascial pain (n = 2) and calcaneal tendinopathy (n = 2) [22–24, 41] and 5 (33.33%) applied EPTE in shoulder impingement (n = 3), lateral epicondylalgia (n = 1), and plantar pain (n = 1) [19, 34, 35, 38, 40]. It was observed that treatments performed with EPTE and EPI were ultrasound-guided, but those carried out with MEP and one with EPI were not [18, 22–24]. In turn, the needle size most frequently used was 0.3 × 25 mm (2.82 cm^2 area) [19, 21–23, 34–39, 42], while the smallest needles, 0.22 × 13 mm (area 0.89 cm^2), were utilized in the treatment of calcaneal tendinopathy in MEP studies [24, 41] and the largest, 0.3 × 40 mm (area 3.76 cm^2), were applied for temporomandibular myofascial pain reduction in 1 EPI study [18].

Regarding the current intensity used, EPI reached the highest values, 3 or 4 mA [18, 21, 36, 37, 42], while the lowest intensities, 0.35 mA (350 μA), were reported in EPTE studies [34, 35, 37]. In MEP applications, intensities fluctuated between 0.45 and 0.6 mA [22–24, 41]. Varied treatment times were observed in the articles, with a range of 3–5 s for electrolysis [18, 21, 36, 37, 42] and 90 s for microelectrolysis [22–24, 34, 35, 37, 41]. The RCTs revealed a total current dose (mA × seg) between a minimum of 9 mC [24] and a maximum of 48 mC [42], with 28 mC being the most frequent [34, 35]. As for the number of sessions, most RCTs described a weekly application for 4–8 weeks, except those by Moreno et al. [36] and Abat et al. [21], in which 2 weekly sessions in acute pubalgia and daily sessions during 2 weeks in patellar tendinopathy were administered, respectively. In turn, MEP studies showed that in myofascial conditions, there was a single session with a follow-up within 1 week [23] and an evaluation at the end of treatment without a follow-up [22].

Considering pain intensity as the main outcome, the most frequently used assessment instrument was the Numeric Pain Rating Scale (NPRS) [19, 34, 35, 37, 38, 40], followed by visual analogue scale (VAS) [18, 23, 24, 37, 42]. These tools were applied to assess pain at rest, at palpation, and in movement. Additionally, the study by Lopez-Martos et al. [18] employed VAS during chewing. It also stands out that algometry served to evaluate the painful pressure threshold in myofascial trigger points [22, 23], subacromial impingement pain, and levator scapulae muscle insertional pain [35, 37, 42].

Some studies used functional questionnaires, such as Shoulder Pain and Disability Index (SPADI) [37] and the Victorian Institute of Sport Assessment for patellar tendinopathy (VISA-P) [21, 39] or for Achilles tendinopathy (VISA-A) [24, 41], which included the evaluation of pain with scales like NPRS. The RCTs presented a decrease in pain at rest and in movement for experimental groups and control groups in relation to the initial evaluation (T0 or baseline) and the follow-up evaluations (T1, T2, ...). Greater changes were observed in the experimental groups, except for the reports by Lopez-Martos et al. [18] on VAS and by de la Barra Ortiz et al. [23] on painful pressure threshold, where pain reduction at rest showed statistically significant differences between the sessions for both groups ($p < 0.005$), but without differences between them (de la Barra Ortiz et al. [23]: T1, $p = 0.052$ and T3, $p = 0.0548$; Lopez-Martos et al. [18]: T1, $p = 0.308$ and T2, $p = 0.023$). Moreover, the study by Ronzio et al. [41] in patients with calcaneal tendinopathy did not reveal statistically significant differences in pain with VAS between the MEP group and the control group after each treatment session ($p = 0.059$), but with favourable changes after completing all intervention sessions ($p < 0.010$). García Naranjo et al. [42] reported statistically significant changes in relation to pain reduction in both groups, with greater differences in the control group.

Range of motion as a secondary outcome was only reported by Rodríguez-Huguet et al. [35], Rodríguez-Huguet et al. [38], and Ronzio et al. [41], where supraspinatus tendinopathy, epicondylitis, and calcaneal tendinopathy were treated. In these studies, an inclinometer [35, 38] and goniometry [41] were used as evaluative instruments. An improvement in range of motion was observed in the 3 RCTs for both groups after treatment and at the follow-up evaluations, with statistically significant differences ($p < 0.05$) in favour of the groups treated with electrolysis modalities. It was only reported by Rodríguez-Huguet et al. [35] that shoulder flexion range did not exhibit statistically significant differences between the groups ($p = 0.096$), although there was an improvement with respect to T0 ($p < 0.01$).

Although it was not explicitly described as range of motion, Lopez-Martos et al. [18] assessed mouth opening, measuring the distance between the incisors. The results showed an improvement in the interincisal space for EPI and dry needling groups, with statistically significant differences between them for the evaluations after the treatment and after the follow-up period ($p = 0.003$).

Changes in muscle strength as a secondary outcome were not reported in the RCTs, with the exception of that by Moreno et al. [36], where pain intensity was assessed with NPRS during hip adductor muscle contraction in patients with pubalgia. Statistically significant differences were reported between the evaluations after treatment and at 2, 4, and 6 months ($p < 0.001$).

This SR shows that disability or functionality assessment was carried out with specific instruments, in accordance with the MSD treated. The articles highlight the use of the Foot and Ankle Ability Measure (FAAM) questionnaire [19], the temporomandibular function test [18], the Blazina functional scale [21, 42], the VISA-P questionnaire [21, 39], the VISA-A questionnaire [24, 41], the Foot and Ankle Disability Index (FADI) [40], the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire [34, 36], the Tegner Activity Scale [21], the SPADI questionnaire [37], the Northwick Park Neck Pain Questionnaire (NPQ) [42], and the Patient-Specific Functional Scale (PSFS) [36]. For the FAAM questionnaire, Fernández-Rodríguez et al. [19] reported a functional improvement in the EPTE group, with statistically significant differences at 1 week and 3 and 12 months ($p < 0.002$). In the study by Lopez-Martos et al. [18], the temporomandibular function test showed an improvement in the EPI group as compared with dry needle treatment ($p = 0.001$) and the control group ($p < 0.01$). In turn, Abat et al. [21] reported 75% of asymptomatic patients and 25% of Blazina category I participants in

groups treated with EPI at the end of follow-up evaluations.

For the VISA-P questionnaire, applied by Abat et al. [21, 39], functional improvement was observed for knee activities in EPI groups ($p < 0.01$). The RCTs by Ronzio et al. [41] and Valentim da Silva et al. [24] showed an improvement in functionality in patients with calcaneal tendinopathy treated with MEP using the VISA-A scale, with statistically significant differences in favour of the experimental groups ($p < 0.05$). For the FADI questionnaire, applied by Iborra-Marcos et al. [40] in patients with plantar fasciitis, a statistically significant improvement was found in the groups treated with EPI and corticosteroids, with greater statistical significance in favour of the experimental group ($p = 0.008$).

For the DASH questionnaire, used by Arias-Buría et al. [34] and de Miguel Valtierra et al. [37], a decrease in disability was observed in patients with supraspinatus tendinopathy, with statistically significant differences in both studies ($p < 0.010$). In turn, for the Tegner scale, which assesses the influence of treatment on return to activity, no statistically significant differences were reported between patients with greater and lesser patellar tendinopathy severity treated with EPI [21]. Finally, the SPADI questionnaire, applied by de Miguel Valtierra et al. [37], NPQ, used by García Naranjo et al. [42], and PSFS, utilized by Moreno et al. [36], reported a statistically significant improvement in functionality among patients with subacromial impingement treated with EPTE, as well as those with acute whiplash syndrome and pubalgia treated with EPI ($p < 0.05$).

Rodríguez-Huguet et al. [38] used the short-form health survey SF-12 to assess the quality of life in the physical and mental dimensions in patients with lateral epicondylalgia. The results did not reveal statistically significant differences between groups treated with EPTE and dry needle in the mental ($p = 0.404$) or physical ($p = 0.94$) dimensions, but favourable changes were observed when intragroup evaluation sessions were compared at the end of treatment, as well as at 1 and 3 months ($p < 0.05$).

In their EPI study on temporomandibular myofascial pain, Lopez-Martos et al. [18] considered patient's tolerance assessment to the electrolysis technique, as well as the tolerance observed by the physical therapist as secondary results. In both cases, the evaluation was performed with the Likert scale. The results showed that the participants presented good tolerance after treatment in both the electrolysis and the dry needle group.

Discussion

The purpose of this SR was to investigate the scientific evidence from the latest decade on the effectiveness of electrolysis modalities as a treatment for MSP. The results suggest that electrolysis or microelectrolysis may constitute therapeutic options for pain reduction in MSDs, decreasing pain intensity and improving functionality.

The 15 RCTs assessed showed a low risk of bias after applying the Cochrane risk of bias tool [32], while 11 of the articles (73.33%) presented good internal validity after being analysed with the PEDro scale, obtaining an average score of 10 [30, 31].

The SR shows that 9 articles (60.00%) reported the use of electrolysis or microelectrolysis as a treatment for tendinopathies [21, 24, 34–39, 41], while 4 studies (26.66%) applied them in myofascial conditions [18, 22, 23, 42] and 2 (13.33%) as treatment in plantar fasciitis [19, 40]. For the tendinopathies group, it was observed that 46.66% applied electrolysis in lower limb disorders, highlighting patellar tendinopathy ($n = 2$) [21, 39], calcaneal tendinopathy ($n = 2$) [24, 41], pubalgia ($n = 1$) [36], and plantar fasciitis ($n = 2$) [19, 40]. Upper limb tendinopathies were included in 3 studies on subacromial impingement (20.00%) [34–36] and 1 on lateral epicondylalgia (6.66%) [38]. It is interesting that most of the studies focused on connective tissue injuries, whose pathophysiology indicated that these conditions were consequences of excessive loads that exceeded the tissue recovery capacity, inducing a pathological regeneration process that could have settled as degeneration if the overload had been perpetuated [43–46]. This can evolve into a chronic pathology in which tissue cellularity is modified and is accompanied by an increase in nerve endings, fatty infiltration, and a blood vessel increase, in contrast to tissue hypoxia [47, 48]. On the other hand, the induction of an inflammatory process in chronic conditions of connective tissues is not a recent phenomenon, to highlight techniques such as deep transverse Cyriax massage, diacutaneous fibrolysis, myofascial release, therapeutic ultrasound, or, more recently, extracorporeal shock wave therapy [49–55]. All these treatments are aimed at inducing an inflammatory process to later achieve a new and efficient tissue repair. However, as they are transcutaneous techniques, they present drawbacks that could be related to their therapeutic precision and difficulty in reaching deep tissues. Electrolysis modalities could exhibit advantages owing to their greater depth (different sizes of needles), specificity of application (energy concentrated on a specific tissue), control of the induced inflammation (determination of a dose through the intensity and time of application), and other effects associated with galvanism, useful to break adhesions (tissue debridement, lysis of water molecules, and formation of caustic substances) [18–23]. Along the same lines, it is highlighted that the tendinopathies reported in the RCTs were mostly classified as chronic pathologies (more than 3 months), which supports the application of electrolysis or microelectrolysis in these conditions, considering that the purpose was to induce tissue repair, starting with an inflammation process [24, 34–37, 40]. As there exist various therapeutic alternatives to promote inflammation, it is suggested to carry out comparative studies to determine if the effectiveness of electrolysis or microelectrolysis is higher than that of other techniques that seek the same therapeutic objective.

Another aspect associated with the therapeutic specificity of electrolysis modalities is the ultrasound-guided support when performing the procedure. This SR shows that 10 of the studies used ultrasound [19, 21, 34–40, 42]; in turn, 4 studies with MEP and 1 with EPI reported the technique without imaging support [18, 22–24, 41]. It should be noted that in these studies, ultrasound support was not used probably because treatment was performed on myofascial trigger points [18, 22, 23], a condition whose imaging diagnosis is controversial, with a greater value ascribed to algometry and clinician examination [56–58]. The other 2 treatments with MEP included applications on the calcaneal tendon [24, 41], anatomically superficial, with easy detection of its tender points through palpatory examination. Therefore, not using of ultrasound is not a problem if the physical examination is adequate, in addition to the fact that the resource is not always available owing to its high cost. It has been established that invasive procedures such as electrolysis, microelectrolysis, or percutaneous electrical nerve stimulation should be performed with ultrasound support to achieve higher treatment specificity and safety; without adequate training in musculoskeletal ultrasound, the technique should not be applied [18, 21, 35–40, 59–61].

However, many applications on superficial tendons such as the calcaneus, patellar, supraspinatus, epicondylar, plantar fascia, or myofascial trigger points can be performed without ultrasound and with a low risk on the basis of a good clinical examination, knowledge of topographic anatomy, and dexterity with the electrolysis or microelectrolysis procedure [22–24, 41]. Along the same lines, the World Confederation of Physical Therapy has declared in the recent years the use of ultrasound as an imaging support to objectify and guide some physical therapy treatments, which creates a need to incorporate these topics into education plans for undergraduate and graduate physical therapists [62, 63]. Thus, ultrasound can be an ally for electrolysis or microelectrolysis application, although, by requiring expertise, it could influence the preference of the therapist for certain MSD applications in accordance with their familiarity with the instrumentation [64, 65]. A recommendation for beginners with this technique is to perform their practice with peripheral and superficial tendons and then gradually incorporate ultrasound into their applications. Another aspect to be taken into consideration is that in percutaneous ultrasound-guided procedures, there is a possibility of needle contamination with gel, although there are no reports of infections or other adverse effects associated with this issue.

This SR highlights the use of NPRS and VAS as main instruments for assessing pain changes in the reported MSDs. These tools improve the quality of the results by the evidence that supports their psychometric properties (NPRS: reliability of 0.95; VAS: reliability of 0.97) [66–69]. The application of NPRS was reported only in the RCTs on EPTE, assessing pain at rest and, in 1 case, in walking [19, 34–38]. In turn, VAS was used in 3 MEP studies [23, 24, 41] and 2 papers on EPI [18, 40], to evaluate pain at rest and, in 1 case, during chewing.

Studies that applied these instruments for functional activity assessment are highlighted as they were able to achieve more potential with these scales [18, 19]. Given the evidence that supports both instruments to objectify changes in pain, the use of these scales is recommended in new studies.

Regarding the study groups reported in the articles, 3 RCTs compared electrolysis or microelectrolysis with sham application [18, 19, 22], obtaining greater and statistically significant analgesic effects in the short and long term in the experimental groups. This is relevant because it supports the analgesic effects of electrolysis modalities, ruling out the influence of placebo effect [70, 71]. It should be noted that 11 RCTs (73.33%) applied electrolysis or microelectrolysis associated with another intervention, most frequently with therapeutic stretching and eccentric exercise ($n = 11$, 73.33%) [19, 21, 23, 24, 34–39, 41], manual therapy techniques ($n = 3$, 20.00%) [24, 36, 41], and therapeutic ultrasound ($n = 1$, 6.66%) [23]. It is noteworthy that the literature highlights benefit with this type of exercise [72–75], manual therapy techniques [76], and therapeutic ultrasound [77] in the MSDs described. The foregoing is of great bioethical value since it provides the participants in the experimental groups with a potential of improvement in their condition if electrolysis or microelectrolysis do not generate changes [78]. It also stands out that controls were treated with therapeutic exercises in 11 RCTs [19, 21, 24, 34–39, 41, 42], physical agents [23, 35, 39, 42], or pharmacology [40, 42], therapeutic alternatives that would also turn out to be beneficial. Only in 2 studies, the control groups did not receive sham treatment without association with another intervention [18, 22].

The main secondary outcome reported in the RCTs was disability/functionality, assessed with different written questionnaires, including FAAM [19], temporomandibular function test [18], the Blazina scale [21, 42], VISA-P [21, 39], VISA-A [24, 41], FADI [40], DASH [34, 37], the Tegner Activity Scale [21], SPADI [37], NPQ [43], and PSFS [36]. After reviewing these functional instruments, the reliability and good correlation were highlighted [79–90]. The foregoing supports the application of these tools in the evaluation of disability and functionality and their post-treatment and follow-up changes; it is therefore suggested that they continue to be considered in future protocols.

Although the electrolysis modalities focus mainly on the resolution of deficiencies such as pain, it is essential to evaluate functional changes associated directly or indirectly with the treatment, especially because physical capacity loss and functional alterations are frequent problems reported in patients with MSDs [1–3]. Despite the improvement in function is not a direct effect attributed to electrolysis or microelectrolysis, it could be explained by analgesia and its influence on the regulation of muscle tone by modifying the neural inputs that affect the discharge of alpha motor neurons, in accordance with the theory of motor system final pathway [91, 92]. Therefore, it is suggested for future protocols to assess functionality through questionnaires or physical tests, taking advantage of the fact that the evidence today offers various validated instruments for each body region [79–90].

It can be observed that in most of the RCTs, electrolysis or microelectrolysis was used once a week for 3–5 weeks, providing favourable results in reducing pain and improving secondary outcomes in MSDs at a short and long term [18, 19, 34, 35, 38, 40–42]. The foregoing is relevant because it supports the physiological foundation of electrolysis that lies in the induction of a controlled inflammation, giving a recovery week for this process to take place, followed by the proliferation phase, whose most essential milestone is the synthesis of collagen [17–23, 35–42]. In some less conservative treatment protocols, participants with patellar tendinopathy of less than 1 month of evolution were treated with 10 sessions in 2 weeks [21] and those with chronic pubalgia were treated with 2 weekly sessions within 12 days [36], which also led to positive effects in reducing pain and improving functionality. The abovementioned could support the hypothesis of many clinicians to induce a sustained pro-inflammatory stimulus in the first stage to ensure a greater tissue regeneration response later on. Likewise, MEP studies in which a single session was applied showed favourable changes in pain and functionality in myofascial conditions, which indicates that fewer applications bring about good results in the short term [22, 23].

Although the results show efficacy with electrolysis or microelectrolysis, the diversity of dosages used is considered a limitation, not clearly reporting the current densities or coulombs delivered for each treatment, parameters that researchers should bear in mind in relationship with the chronicity of the condition, period of tissue repair, or magnitude of pain [18, 19, 22, 23, 34–36, 39, 41, 42]. In this SR, the calculation of the current dose was made to try to compare electrolysis or microelectrolysis treatments with one another (Table 3, see end of paper). In many studies, it was not possible to determine the exact dose since not enough parameters were reported. On the other hand, numerous RCTs indicated that the most frequent dose was close to 28 mC, with a minimum dose of 9 mC, so new protocols should consider these values as reference, adapting intensities and treatment times to achieve these values [19, 24, 34, 35, 38, 40]. It should be emphasized that dose determination is not simple; in several studies, the current emission depended on the patient tolerance, which means that times of emission varied with constant intensity. It is recommended for future studies to specify

the intensities, total treatment time, needle size, and current density used as report variables to achieve standardization of dosages in electrolysis or microelectrolysis.

The results of this SR recommend the application of electrolysis or microelectrolysis as MSP treatment, so a next challenge may be a comparison between the electrolysis modalities to establish the potential therapeutic differences between them. Although both techniques use the same current, the main difference is the delivery of energy to the tissues, which would be fast in electrolysis applications and progressive in microelectrolysis applications. This is relevant since it can condition more comfortable or uncomfortable responses during the procedure, which could determine the preferences of users in favour of microelectrolysis if the therapeutic results do not differ.

Conclusions

The modalities of galvanic electrolysis are recent in physical therapy and have been proposed for pain management in MSDs. This SR indicates that electrolysis and microelectrolysis are effective in reducing pain and improving functionality in various MSDs in the short and long term. However, although the results are favourable, it is necessary to review the dosages used, improving the parameters reported in the new protocols to establish a consensus in dosage recommendations with these treatments. Despite both electrolysis modalities are effective in reducing MSP, comparative studies are suggested to establish if there are therapeutic differences between them, as well as to document user's comfort with both procedures. Moreover, the main MSDs described in this SR included knee and shoulder tendinopathies, so it is advisable to increase the evidence for elbow, wrist, and hip tendinopathies, as well as for myofascial pain.

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Conflict of interest

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'+' means low risk of bias; '–' means high risk of bias; '?' means unknown risk of bias
Trials involving 3 or more high risks of bias were considered as of poor methodological quality.

Figure 2. Included studies graded in accordance with the Cochrane risk of bias tool

Table 1. PEDro scale scores of the analysed studies

Study	Title	Author, publication year	PEDro scale criteria*											Total score
			1**	2	3	4	5	6	7	8	9	10	11	
1	Randomized, double-blind study comparing percutaneous electrolysis and dry needling for the management of temporomandibular myofascial pain	Lopez-Martos et al. (2018) [18]	1	1	1	1	1	1	1	1	1	1	1	10/10
2	Prospective randomized trial of electrolysis for chronic plantar heel pain	Fernández-Rodríguez et al. (2018) [19]	1	1	1	1	1	1	1	1	1	1	1	10/10
3	Clinical results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) and eccentric exercise in the treatment of patellar tendinopathy	Abat et al. 2015) [21]	1	0	0	1	0	0	0	0	1	1	1	4/10
4	Effects in pressure-pain threshold of percutaneous galvanic microcurrent in the trapezius trigger points	Ronzio et al. (2015) [22]	1	0	0	0	0	0	0	1	1	1	1	4/10
5	Effectiveness of percutaneous microelectrolysis and ultrasound in decreasing pain in myofascial trigger points: evaluation through algometry and visual analogue scale	de la Barra Ortiz et al. (2020) [23]	1	1	1	1	1	1	1	1	1	1	1	10/10
6	Ultrasound-guided percutaneous electrolysis and eccentric exercises for subacromial pain syndrome: a randomized clinical trial	Arias-Buría et al. (2015) [34]	1	1	1	1	1	0	1	1	1	1	1	9/10
7	Effectiveness of percutaneous electrolysis in supraspinatus tendinopathy: a single-blinded randomized controlled trial	Rodríguez-Huguet et al. (2020) [35]	1	1	1	1	1	0	0	1	1	1	1	8/10
8	Intratissue percutaneous electrolysis vs corticosteroid infiltration for the treatment of plantar fasciosis	Iborra-Marcos et al. (2018) [40]	1	0	0	1	0	0	0	1	1	0	1	4/10
9	Intratissue percutaneous electrolysis combined with active physical therapy for the treatment of adductor longus enthesopathy-related groin pain: a randomized trial	Moreno et al. (2017) [36]	1	1	1	1	1	0	1	1	1	1	1	9/10
10	Ultrasound-guided application of percutaneous electrolysis as an adjunct to exercise and manual therapy for subacromial pain syndrome: a randomized clinical trial	de Miguel Valtierra et al. (2018) [37]	1	1	1	1	1	0	1	1	1	1	1	9/10
11	Percutaneous electrolysis in the treatment of lateral epicondylalgia: a single-blind randomized controlled trial	Rodríguez-Huguet et al. (2020) [38]	1	1	1	1	1	1	1	1	1	1	1	10/10
12	Randomized controlled trial comparing the effectiveness of the ultrasound-guided galvanic electrolysis technique (USGET) versus conventional electro-physiotherapeutic treatment on patellar tendinopathy	Abat et al. (2016) [39]	1	1	1	1	1	0	1	1	1	1	1	9/10
13	Effects of Microelectrólisis Percutaneous® on pain and functionality in patients with calcaneal tendinopathy	da Silva et al. (2014) [24]	1	1	1	1	1	0	1	1	1	1	1	9/10
14	Effects of percutaneous microelectrolysis (MEP®) on pain, ROM and morning stiffness in patients with Achilles tendinopathy	Ronzio et al. (2017) [41]	0	1	1	0	1	0	0	0	1	1	0	4/10
15	A novel approach in the treatment of acute whiplash syndrome: ultrasound-guided needle percutaneous electrolysis. A randomized controlled trial	García Naranjo et al. (2017) [42]	1	0	0	1	0	0	0	0	1	1	1	4/10

* PEDro scale criteria: 1. The selection criteria were specified. 2. Subjects were randomized into groups (in a crossover study, subjects were randomized as they received treatments). 3. The assignment was hidden. 4. The groups were similar at the beginning in relation to the most important prognostic indicators. 5. All subjects were blinded. 6. All therapists who administered the therapy were blinded. 7. All assessors who measured at least 1 key outcome were blinded. 8. Measures of at least 1 of the key outcomes were obtained from more than 85% of the subjects initially assigned to the groups. 9. Results were presented for all subjects who received treatment or were assigned to the control group or, when this could not be the case, data for at least 1 key outcome were analysed by 'intention to treat'. 10. Results of statistical comparisons between groups were reported for at least 1 key outcome. 11. The study provides point and variability measures for at least 1 key outcome.

** The eligibility criteria item does not contribute to the total score.

Table 2. Characteristics of the included studies

Study	Author, publication year	Musculoskeletal disorder	Type of study	Sample (*n*), mean age	EG, CG	Intervention	Electrolysis sessions	Outcomes	Evaluation time	Conclusions
1	López-Martos et al. (2018) [18]	Temporomandibular myofascial pain (6 months or more of pain)	RCT	60 Men: 8 (13.3%) Women: 52 (86.7%) Mean age: 38 years	EG: *n* = 20 5 men, 15 women CG1: *n* = 20 2 men, 18 women CG2: *n* = 20 1 man, 19 women	EG: EPI in lateral pterygoid muscle CG1: TDN in lateral pterygoid muscle CG2: sham EPI in lateral pterygoid muscle	1 session per week for 3 weeks	Main outcomes: – Pain intensity at rest (VAS) – Chewing pain intensity (VAS) Secondary outcomes: – Interincisal distance (TheraBite® System ruler) – Function (temporomandibular function test) – Patient treatment tolerance (Likert scale) – Observer treatment tolerance assessment (Likert scale)	T0: baseline T1: 28 days T2: 42 days T3: 70 days	Main outcomes: – Pain intensity at rest: EG* = CG1* < CG2 (T1, T2, and T3) – Chewing pain intensity: EG* = CG1* < CG2 (T1, T2, and T3) Secondary outcomes: – Interincisal distance (TheraBite® System ruler): EG* > CG1* > CG2 (T1, T2, and T3) – Function (temporomandibular function test): EG < CG1* > CG2 (T1 and T2), EG* = CG1* > CG2 (T3) – Patient treatment tolerance (Likert scale): EG* > CG1* > CG2 (T3) (T1 and T2 not reported) – Observer treatment tolerance assessment (Likert scale): EG* > CG1* > CG2 (T3) (T1 and T2 not reported)
2	Fernández-Rodríguez et al. (2018) [19]	Chronic heel pain (3 months of pain)	RCT	67 Men: 25 (37.3%) Women: 42 (62.7%) Mean age: 45 years	EG: *n* = 38 15 men, 23 women CG: *n* = 29 10 men, 19 women	EG: EPTE in plantar fascia + therapeutic exercises CG2: sham EPTE in plantar fascia + therapeutic exercises	1 session per week for 5 weeks	Main outcome: – Pain intensity at walking (first steps in the morning) (NPRS) Secondary outcomes: – Foot and ankle function (FAAM questionnaire) – Plantar fascia thickness (US)	T0: baseline T1: 1 week T2: 3 months T3: 12 months	Main outcome: – Pain intensity at walking (first steps in the morning) (NPRS): EG* < CG = baseline (T1), EG* < CG* < baseline (T2 and T3) Secondary outcomes: – Foot function (FAAM questionnaire): EG* > CG = baseline (T1), EG* > CG > baseline (T2 and T3) – Plantar fascia thickness: EG = CG = baseline (T1, T2, and T3)
3	Abat et al. (2015) [21]	Patellar tendinopathy (1 month or more of pain)	RCT	40 Men: 35 (87.5%) Women: 5 (12.5%) Mean age: 26 years	EG1: *n* = 21 17 men, 4 women EG2: *n* = 19 18 men, 1 woman	EG1 (VISA-P < 50 points): EPI in patellar tendon + eccentric exercises (2 times a week) EG2 (VISA-P > 50 points): EPI in patellar tendon + eccentric exercises (2 times a week) 2 experimental groups classified in accordance with severity with the VISA-P scale	daily sessions for 2 weeks (10 sessions)	Main outcome: – Knee pain in functional activities (VISA-P) Secondary outcomes: – Functional assessment (Blazina scale) – Influence of treatment on return to sports activity (Tegner scale) – User satisfaction (Roles and Maudsley score)	T0: baseline T1: 3 months T2: 2 years T3: 5 years T4: 10 years	Main outcome: – Knee pain in functional activities (VISA-P): EG1* > EG2* > baseline (T1), EG1 = EG2 > baseline (T2, T3, and T4) Secondary outcomes: – Functional assessment (Blazina scale): 75% of asymptomatic patients and 25% Blazina I (T1, T2, and T3) – Influence of treatment on return to sports activity (Tegner scale): EG1 = EG2 > baseline (T1, T2, T3, and T4) – User satisfaction (Roles and Maudsley score): EG1* = EG2* > baseline (T1, T2, T3, and T4)
4	Ronzio et al. (2015) [22]	Upper trapezius myofascial trigger points (pain time not reported)	RCT	16 Men: 4 (25.0%) Women: 12 (75.0%) Mean age: 24 years	EG: *n* = 8 NS CG: *n* = 8 NS	EG: MEP CG: sham MEP	1 session	Main outcome: – PPT (algometry) Secondary outcome: – Technique tolerance (VAS)	T0: baseline T1: 1 min T2: 10 min	Main outcome: – PPT (algometry): EG* > CG (T1 and T2) Secondary outcome: – Technique tolerance (VAS): EG* > CG (T1 and T2)

5	de la Barra Ortiz et al. (2020) [23]	Upper trapezius myofascial trigger points (pain time not reported)	RCT	48 Men: 23 (47.9%) Women: 25 (52.1%) Mean age: 22 years	EG: *n* = 24 11 men, 13 women CG: *n* = 24 12 men, 12 women	EG: US + MEP CG: US	1 session	Main outcomes: – Pain (VAS) – PPT (algometry) Secondary outcomes: not reported	T0: baseline T1: after treatment T2: 3 days T3: 7 days	Main outcomes: – Pain (VAS): EG* = CG* < baseline (1 day), EG* < CG* < baseline (T2 and T3) – Pain (pressure algometry): EG* = CG* > baseline (1 day), EG* > CG* > baseline (T2 and T3)
6	Arias-Buría et al. (2015) [34]	Subacromial impingement (3 months or more of pain)	RCT	36 Men: 9 (25.0%) Women: 27 (75.0%) Mean age: 57 years	EG: *n* = 17 4 men, 13 women CG: *n* = 19 5 men, 14 women	EG: EPTE + eccentric exercises (3 exercise modalities, 3 sets of 10 repetitions, 2 times a day for 4 weeks) CG: eccentric exercises (3 exercise modes, 3 sets of 10 repetitions, 2 times a day for 4 weeks)	1 session per week for 4 weeks	Main outcome: – Minimal pain, average pain, and most severe pain (NPRS) Secondary outcome: – Upper limb functionality (DASH questionnaire)	T0: baseline T1: session 2 T2: session 3	Main outcome: – Minimal pain, average pain, and most severe pain (NPRS): EG* < CG* = baseline (T1 and T2) Secondary outcome: – Upper limb functionality (DASH questionnaire): EG* > CG* = baseline (T1 and T2)
7	Rodríguez-Huguet et al. (2020) [35]	Supraspinatus muscle tendinopathy (less than 3 months of pain)	RCT	36 Men: 27 (75.0%) Women: 9 (25.0%) Mean age: 43 years	EG: *n* = 18 16 men, 2 women CG: *n* = 18 11 men, 7 women	EG: EPTE + eccentric exercises (3 exercise modalities, 3 sets of 10 repetitions, 1 time per day for 4 weeks) CG: TDN + eccentric exercises (3 exercise modalities, 3 sets of 10 repetitions, 1 time per day for 4 weeks)	1 session per week for 4 weeks	Main outcomes: – Pain (NPRS) – PPT (algometry) Secondary outcome: – ROM (inclinometer)	T0: baseline T1: end of treatment T2: 1 month T3: 1 year	Main outcomes: – Pain (NPRS): EG* > CG* > baseline (T3), EG = CG > baseline (T1 and T2) – PPT (algometry): EG* > CG* > baseline (T1, T2, and T3) Secondary outcome: – ROM in abduction, external rotation, internal rotation, and extension (inclinometer): EG* > CG* > baseline (T1, T2, and T3); ROM in flexion (inclinometer): EG = CG > baseline (T1, T2, and T3)
8	Iborra-Marcos et al. (2018) [40]	Plantar fasciitis (3 months or more of pain)	RCT	64 Men: 35 (54.7%) Women: 29 (45.3%) Mean age: 46 years	EG: *n* = 32 NS CG: *n* = 32 NS	EG: EPI CG: corticosteroid injections (day 1 and day 7)	1 session per week for 10 weeks	Main outcome: – Pain (VAS) Secondary outcomes: – Plantar fascia thickness (US) – Functionality (FADI questionnaire)	T0: baseline T1: 3 months T2: 6 months T3: 12 months	Main outcome: – Pain (VAS): CG* > EG* > baseline (T1, T2, and T3) Secondary outcomes: – Plantar fascia thickness (US): CG* > EG* > baseline (T1, T2, and T3) – Functionality (FADI): CG* > EG* > baseline (T1, T2, and T3)
9	Moreno et al. (2017) [36]	Long approximator muscle tendinopathy (less than 3 months of pain)	RCT	24 Men: 24 (100%) Women: 0 (0%) Mean age: 26 years	EG: *n* = 11 11 men, 0 women CG: *n* = 13 13 men, 0 women	EG: EPI + APT (therapeutic exercises in 3 phases of progression) CG: APT (therapeutic exercises in 3 phases of progression)	2 sessions per week during phase 1 of APT (average duration: 12 days for EG and 20 days for CG)	Main outcome: – Pain palpation and pain contraction (NPRS) Secondary outcome: – Functionality (PSFS)	T0: baseline T1: end of treatment T2: 2 months T3: 4 months T4: 6 months	Main outcome: – Pain palpation and pain contraction (NPRS): EG* < CG* < baseline (T1, T2, T3, and T4) Secondary outcome: – Functionality (PSFS): EG* < CG* < baseline (T1, T2, T3, and T4)

10	de Miguel Valtierra et al. (2018) [37]	Subacromial impingement (3 months or more of pain)	RCT	50 Men: 23 (46.0%) Women: 27 (54.0%) Mean age: 55 years	EG: *n* = 25 12 men, 13 women CG: *n* = 25 11 men, 14 women	EG: EPTE + manual therapy + eccentric exercises (3 exercise modalities, 3 sets of 10 repetitions, 2 times a day for 4 weeks) CG: manual therapy + eccentric exercises (3 exercise modalities, 3 sets of 10 repetitions, 2 times a day for 4 weeks)	1 session per week for 5 weeks	Main outcome: – Pain (NPRS) Secondary outcomes: – Average PPT: zygapophysial C5/C6, deltoid, second metacarpal, and anterior tibial muscles (algometry) – Disability (DASH questionnaire) – Shoulder function (SPADI questionnaire) – Improvement self-report (GROC questionnaire)	T0: baseline T1: end of treatment T2: 3 months T3: 6 months	Main outcome: – Pain (NPRS): EG* < CG* < baseline (T1, T2, and T3) Secondary outcomes: – Average PPT: zygapophysial C5/C6, deltoid, second metacarpal, and anterior tibial muscles (algometry): EG* < CG < baseline (T1, T2, and T3) – Disability (DASH): EG* < CG < baseline (T1, T2, and T3) – Shoulder function (SPADI): EG* < CG < baseline (T1, T2, and T3) – Improvement self-report (GROC): EG = CG (both groups provided similar self-reports for T1, T2, and T3)
11	Rodríguez-Huguet et al. (2020) [38]	Epicondylitis (pain time not reported)	RCT	32 Men: 20 (62.5%) Women: 12 (37.5%) Mean age: 39 years	EG: *n* = 16 10 men, 6 women CG: *n* = 16 10 men, 6 women	EG: EPTE in lateral epicondyle + daily eccentric exercise program (for 4 weeks) CG: TDN in lateral epicondyle + daily eccentric exercise program (for 4 weeks)	1 session per week for 4 weeks	Main outcomes: – Pain (NPRS) – PPT (algometry) Secondary outcomes: – ROM (inclinometer) – Life quality (SF-12)	T0: baseline T1: end of treatment T2: 1 month T3: 3 months	Main outcomes: – Pain (NPRS): EG* > CG* > baseline (T1, T2, and T3) – PPT (algometry): EG* > CG* > baseline (T2 and T3) Secondary outcomes: – ROM (inclinometer) for flexion: EG* > CG* > baseline (T2 and T3) – Quality of life (SF-12): EG = CG > baseline (T1, T2, and T3)
12	Abat et al. (2016) [39]	Patellar tendinopathy (1 month or more of pain)	RCT	64 Men: 51 (79.7%) Women: 13 (20.3%) Mean age: 31 years	EG: *n* = 32 24 men, 8 women CG: *n* = 32 27 men, 5 women	EG: EPI in patellar tendon + eccentric exercises unipodal squat (3 sets, 15 repetitions) CG: US + laser + ICT + eccentric exercises unipodal squat (3 series, 15 repetitions), 3 days a week for 8 weeks	1 session every 2 weeks for 8 weeks	Main outcome: – Knee pain in functional activities (VISA-P) Secondary outcomes: not reported	T0: baseline T1: end of treatment	Main outcome: – Knee pain in functional activities (VISA-P): EG* > CG > baseline (T1)
13	da Silva et al. (2014) [24]	Calcaneal tendinopathy (6 months or more of pain)	RCT	20 Men: NS Women: NS Mean age: 45 years	EG: *n* = 10 NS CG: *n* = 10 NS	EG: warm-up on a stationary bike + MEP of calcaneal tendon + stretching exercises (adductors, abductors, hamstrings, and plantar flexors, 3 sets 30 s) + DTM of calcaneal tendon + plantar fascia stretch + eccentric exercises (3 series of 15 repetitions), 2 sessions per week CG: warm-up on a stationary bike + stretching exercises (adductors, abductors, hamstrings, and plantar flexors, 3 sets 30 s) + DTM of calcaneal tendon + plantar fascia stretch + eccentric exercises (3 series of 15 repetitions), 2 sessions per week	1 session per week for 4 weeks	Main outcome: – Pain (VISA-A) Secondary outcomes: – ROM (goniometry) – Functionality (VISA-A)	T0: baseline T1: 1 month	Main outcome: – Pain with VISA-A (VAS): EG* > CG > baseline (T1) Secondary outcomes: – Functionality (VISA-A): EG* > CG > baseline (T1)

14	Ronzio et al. (2017) [41]	Calcaneal tendinopathy (pain time not reported)	RCT	20 Men: NS Women: NS Mean age: NS	EG: *n* = 10 NS CG: *n* = 10 NS	EG: warm-up on a stationary bike + MEP of calcaneal tendon + stretching exercises (adductors, abductors, hamstrings, and plantar flexors, 3 sets 30 s) + DTM of calcaneal tendon + eccentric exercises (3 series, 15 repetitions), 2 sessions per week CG: warm-up on a stationary bike + stretching exercises (adductors, abductors, hamstrings, and plantar flexors, 3 sets 30 s) + DTM of calcaneal tendon + eccentric exercises (3 sets, 15 repetitions), 2 sessions per week	1 session per week for 4 weeks	Main outcome: – Pain (VAS) Secondary outcomes: – ROM (goniometry) – Functionality (VISA-A)	T0: baseline T1: end of each session T2: 1 month	Main outcome: – Pain (VAS): EG = CG > baseline (T1), EG* > CG > baseline (T2) Secondary outcomes: – ROM (goniometry): EG* > CG > baseline (T1 and T2) – Functionality (VISA-A): EG* > CG > baseline (T1 and T2)
15	García Naranjo et al. (2017) [42]	Acute cervical whiplash syndrome (Quebec grade II) (less than 3 months)	RCT	100 Men: 36 (36%) Women: 64 (64%) Mean age: 38 years	EG: *n* = 50 16 men, 34 women CG: *n* = 50 20 men, 30 women	EG: EPI in distal insertion of levator scapulae muscle CG: MWT + TENS + US + massage + therapeutic exercises (cervical and scapulothoracic stretching, 20 min), 5 weekly sessions for 1 month Pharmacology was not restricted for either group	1 session per week for 3 weeks	Main outcomes: – Pain (VAS) – PPT (algometry) Secondary outcome: – Disability (NPQ)	T0: baseline T1: 1 month	Main outcomes: – Pain (VAS): CG* > EG* > baseline – PPT (algometry): CG* > EG* > baseline Secondary outcome: – Disability (NPQ): EG* < CG* < baseline

APT – active physical therapy program
CG – control group
DASH – Disabilities of the Arm, Shoulder and Hand
DTM – deep transverse massage
EG – experimental group
EPI – percutaneous intratissue electrolysis
EPTE – therapeutic percutaneous electrolysis
FAAM – Foot and Ankle Ability Measure
FADI – Foot and Ankle Disability Index
GROC – Global Rating of Change
ICT – interferential current therapy
MEP – percutaneous microelectrolysis
MWT – microwave therapy
NPQ – Northwick Park Neck Pain Questionnaire
NPRS – Numeric Pain Rating Scale
NS – not specified
PPT – painful pressure threshold
PSFS – Patient-Specific Functional Scale
RCT – randomized clinical trial
ROM – range of motion
SF-12 – 12-item short-form health survey
SPADI – Shoulder Pain and Disability Index
T – time point
TDN – trigger point dry needling
TENS – transcutaneous electrical nerve stimulation
US – ultrasound
VAS – visual analogue scale
VISA-A – Victorian Institute of Sport Assessment for Achilles tendinopathy
VISA-P – Victorian Institute of Sport Assessment for patellar tendinopathy

* $p < 0.05$

Table 3. Types of electrolysis used in the included studies

Study	Author, publication year	Musculoskeletal disorder	Electrolysis parameters	Electrolysis sessions
1	Lopez-Martos et al. (2018) [18]	Temporomandibular myofascial pain (6 months or more of pain)	EPI Ultrasound-guided: no Needle: diameter 0.25 mm, length 40 mm Intensity: 2 mA Application time: 3 s Series: 3 Dose: 18 mC	1 session per week for 3 weeks
2	Fernández-Rodríguez et al. (2018) [19]	Chronic heel pain (3 months of pain)	EPTE Ultrasound-guided: yes Needle: diameter 0.35 mm, length 40 mm Intensity: not reported Application time: not reported Series: not reported Dose: 28 mC	1 session per week for 5 weeks
3	Abat et al. (2015) [21]	Patellar tendinopathy (1 month or more pain)	EPI Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 3 mA Application time: not reported Series: 3 Dose: not reported	daily sessions for 2 weeks (10 sessions)
4	Ronzio et al. (2015) [22]	Upper trapezius myofascial trigger points (pain time not reported)	MEP Ultrasound-guided: no Needle: diameter 0.3 mm, length 25 mm Intensity: 0.5 mA Application time: 3 min or up to the participant's tolerance level Series: 1 Dose: not reported	1 session
5	de la Barra Ortiz et al. (2020) [23]	Upper trapezius myofascial trigger points (pain time not reported)	MEP Ultrasound-guided: no Needle: diameter 0.3 mm, length 25 mm Intensity: 0.6 mA Application time: 3 min or up to the participant's tolerance level Sets: 3 to patient's tolerance, 30-s pause between sets Dose: not reported	1 session
6	Arias-Buría et al. (2015) [34]	Subacromial impingement (3 months or more of pain)	EPTE Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 350 µA Application time: 80 s Series: not reported Dose: 28 mC	1 session per week for 4 weeks
7	Rodríguez-Huguet et al. (2020) [35]	Supraspinatus muscle tendinopathy (less than 3 months of pain)	EPTE Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 350 µA Application time: 80 s Series: not reported Dose: 28 mC	1 session per week for 4 weeks
8	Iborra-Marcos et al. (2018) [40]	Plantar fasciitis (3 months or more of pain)	EPI Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 3 mA Application time: 5 s Series: not reported Dose: 15 mC	1 session per week for 10 weeks

9	Moreno et al. (2017) [36]	Long approximator muscle tendinopathy (less than 3 months of pain)	EPI Ultrasound-guided: yes Needle: diameter 0.33, length 50 mm Intensity: 3 mA Application time: 5 s Series: 3 Dose: 15 mC	2 sessions per week during phase 1 of active physical therapy program (average duration: 12 days for experimental group, 20 days for control group)
10	de Miguel Valtierra et al. (2018) [37]	Subacromial impingement (3 months or more of pain)	EPTE Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 350 µA Application time: 90 s Series: not reported Dose: 31.5 mC	1 session per week for 5 weeks
11	Rodríguez-Huguet et al. (2020) [38]	Epicondylitis (pain time not reported)	EPTE Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 350 µA Application time: 80 s Series: not reported Dose: 28 mC	1 session per week for 4 weeks
12	Abat et al. (2016) [39]	Patellar tendinopathy (1 month or more of pain)	EPI Ultrasound-guided: yes Needle: diameter 0.25 mm, length 25 mm Intensity: 2 mA Application time: not reported Series: 3 Dose: not reported	1 session every 2 weeks for 8 weeks
13	da Silva et al. (2014) [24]	Calcaneal tendinopathy (6 months or more of pain)	MEP Ultrasound-guided: no Needle: diameter 0.22 mm, length 13 mm Intensity: 450 µA Application time: 20 s Series: 3 × 3 points Dose: 27 mC	1 session per week for 4 weeks
14	Ronzio et al. (2017) [41]	Calcaneal tendinopathy (pain time not reported)	MEP Ultrasound-guided: no Needle: diameter 0.22 mm, length 13 mm Intensity: 450 µA Application time: 20 s Series: 3 Dose: 9 mC	2 sessions per week for 4 weeks
15	García Naranjo et al. (2017) [42]	Acute cervical whiplash syndrome (Quebec grade II) (less than 3 months)	EPI Ultrasound-guided: yes Needle: diameter 0.3 mm, length 25 mm Intensity: 3 mA Application time: 5 s Series: not reported Dose: 15 mC	1 session per week for 3 weeks

EPI – percutaneous intratissue electrolysis
EPTE – therapeutic percutaneous electrolysis
MEP – percutaneous microelectrolysis